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A brief historic survey which places programed instruction in the proper perspective relative to behavioral technology as a whole is presented.

Behavioral technology is the application of learning theory to practical problems of training and education. The application of behavioral technology to the teaching of certain verbal and intellectual skills is known as "programed instruction."

The main points in developing a program are: staff personnel including subject matter experts, behavior analysts, programers, project administrators, test subjects, program editors, typists, draftsmen, and illustrators; the specification of objectives; behavioral analysis; frame writing and testing; and the economics of program production.

Behavioral technology suggests many general approaches to a manpower development program. Current activity in the field includes: programed instruction in industry for maintenance personnel, technical sales representatives, engineers, and computer programers; programed instruction in the military; the development of educational programs for the schools; programed instruction for post-graduate medical education; and programed instruction in underdeveloped areas.

Issues in the use and future development of programed instruction include the role of the teacher, the degree of deterioration in educational objectives, programed instruction and teacher training, administrative problems, centralization of control of education, quality control, and some pseudo-problems.

Areas for research include literacy; task analysis; behavioral analysis techniques; evaluation techniques; the training of program production teams and project managers; problems of implementation and installation, and the teaching of languages, science, manipulative and mechanical skills, and social interaction skills.

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INSTRUCTIONAL TECHNOLOGY - U.S.C.

# *Behavioral Technology and Manpower Development*

*By Francis Mechner, Ph.D. and Donald A. Cook, Ph.D.*

1983

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# BEHAVIORAL TECHNOLOGY AND MANPOWER DEVELOPMENT

A background paper prepared for the

Directorate of Scientific Affairs,
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by

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# TABLE OF CONTENTS


| | | Page |
|---|---|---|
| I | The Need | 1 |
| II | A Brief Historic Survey of the Field | 1 |
| III | Behavioral Technology | 2 |
| IV | Programmed Instruction | 4 |
| | A. Examples | 4 |
| | 1. Atomic Number | 4 |
| | 2. Ohm's Law | 7 |
| | 3. Squaring Numbers Ending in 5 | 10 |
| | 4. Listening | 12 |
| | B. Characteristics of Programmed Instruction | 12 |
| | 1. Small Steps | 12 |
| | 2. Active Response | 12 |
| | 3. Immediate Confirmation | 13 |
| | 4. Low Error Rates | 13 |
| | 5. Self-Pacing | 13 |
| | 6. Operationally Defined Objectives | 13 |
| | C. Techniques of Programming | 14 |
| | 1. The Response Mode | 14 |
| | 2. Branching Techniques | 14 |

V How a Program Is Developed 15

A. Staffing and Economics 15

B. The Specification of Objectives (Task Analysis) 16

C. Behavioral Analysis 17

D. Frame Writing and Testing 18

E. The Economics of Program Production 19

VI Applications of Behavioral Technology to Manpower Development 20

VII Current Activity in the Field 24

A. Programmed Instruction in Industry 24

1. The Training of Plant Operations and Maintenance Personnel 24

2. The Training of Technical Sales Representatives 25

3. The Training of Engineers 26

4. The Training of Computer Programmers 26

5. Teaching Communication Skills 27

B. Programmed Instruction for Training in the Military 27

C. The Development of Educational Programs for the Schools 30

D. Programmed Instruction for Post-Graduate Medical Education 31

E. Programmed Instruction in Underdeveloped Areas 36

VIII Teaching Machines 36

IX Issues in the Use and Future Development of Programmed Instruction 37

A. What Is the Role of the Teacher? 37

B. The Danger of Deteriorating Educational Objectives 38

C. Programmed Instruction and Teacher Training 38

D. Administrative Problems 39

E. Centralization of the Control of Education 39

F. Quality Control 40

G. Some Pseudo-problems 41

X Some Areas for Research 42

A. Subject Matter Areas Which Have As Yet Received Little Attention 42

1. Literacy 42

2. Language Teaching 43

3. Science Education 43

4. The Teaching of Manipulative and Mechanical Skills 43

5. The Teaching of Social Interaction Skills 43

B. Problems in the Area of Production Technology 44

1. Task Analysis Techniques 44

2. Behavioral Analysis Techniques 44

3. Evaluation Techniques 44

4. The Training of Program Production Teams and Project Management 45

C. Problems of Implementation and Installation 45

## INTRODUCTORY NOTE

The technology the applications of which form the subject of this paper is the outgrowth of behavioral science. While this technology is still comparatively young, certainly much younger than the science on which it is based, it is already successful and wide-ranging in its initial applications. Programmed instruction is one of these. Others include the design of organizations, work environments, and other contingency structures. Manpower development systems, educational systems, and curricula depend for their successful design upon the correct application of behavioral technology, with programmed instruction serving as a versatile and powerful tool when it is correctly integrated into the total system.

## I. THE NEED

During the last ten years, the world's teacher shortage has increased. Since economic expansion is always predicated upon the development of technical manpower, the economic growth objectives which many of the world's developing countries have set themselves require education and training on an unprecedented scale. If carried out by traditional methods, such education programs would require several times as many instructors as are now available. Since no quick solution for the teacher shortage is in sight, a new approach to manpower development is needed. Certain recent advances in behavioral technology offer an approach that holds considerable promise.

The following sections describe some of these advances as they relate to the problems of manpower development.

In order to place programmed instruction in the proper perspective relative to behavioral technology as a whole, a brief historic survey of the field is presented.

## II. A BRIEF HISTORIC SURVEY

The field of psychology began its maturation period around the turn of the century when Pavlov and Thorndike laid some of the early foundations of a "science of behavior." Thorndike's work in particular, because of its emphasis on the organism's interaction with its environment, provided a broad base on which subsequent investigators were able to build. Thorndike's skillful use of objective measures of behavior under closely controlled conditions provided his successors with a methodology. His theoretical contributions—such as the principle that rewarded behavior tends to occur again; that unrewarded behavior tends to disappear; and that sheer repetition of the behavior does not strengthen it—laid the foundation of modern learning theory (65).

During the following thirty years, experimental psychology underwent a period of development and ferment. Many schools and theories of psychology were born and died. Hull (30) and his students (61, 62) made significant contributions to our understanding of the role of drive and motivation in learning, and to the literature on discrimination learning, generalization, and concept formation (60). Hull on one side of the Atlantic and Piaget on the other (45) showed that abstract concepts are learned by generalization from concrete instances, and that in concept learning, the specific must precede the general. Keller and Schoenfeld's elegant summary of the principle is that a concept involves generalization within a class and discrimination between that class and other classes (33). Keller's monograph, Learning: Reinforcement Theory, provides a good summary of the basic principles (32).

The field of learning received a very significant impetus from the work of B. F. Skinner of Harvard. In The Behavior of Organisms (1938) (50) he set forth a new methodology for the experimental analysis of behavior that set off a wave of research activity which is still

on the increase. The most significant feature of this methodology was the use of the "free operant" and of response rate as an important measure of behavior. In this book, Skinner first described an experimental analysis of chaining, which is today seen as the basic mechanism for the learning of complex skills.

Practical applications of Skinner's findings began to appear with increasing frequency. Among the best known of these are the training of circus animals (3, 20, 23, 31), the training of pigeons and chimpanzees as pilots of missiles and space vehicles (53), the training of laboratory animals in connection with psychopharmacological research (16). In an attempt to show that learning theory has important applications in many domains of human behavior, Skinner wrote Science and Human Behavior (1953) (55). In Verbal Behavior (1957) (58) he showed that verbal behavior is governed by the same principles as any other behavior.

During World War II, Keller applied learning theory principles to the teaching of Morse Code (34). He developed a program of instruction which featured immediate feedback to the learner, gradual increments in the speed with which the learner was receiving the Code, and emphasis on the application of discrimination training principles. The result was a substantial increase in the speed with which Morse Code could be learned.

In 1954 Skinner stimulated the application of learning theory to training and education with his article "The Science of Learning and the Art of Teaching" (56). His 1958 paper "Teaching Machines" (57) provided the final boost. In the same year, the Journal of the Experimental Analysis of Behavior was founded. This journal is now a leading vehicle for the publication of behavioral research.

## III. BEHAVIORAL TECHNOLOGY

During the nineteen fifties, practical applications of learning theory multiplied so rapidly that a specialized discipline called behavioral technology has come to be recognized. Applications were found in the fields of industrial and military training, human engineering and man-machine systems.

Behavioral technology may be defined as the detailed application of learning theory to practical problems of training and education. The behavioral technologist approaches problems in a basically operational manner, a manner which focuses attention on the behavior to be produced. The following is a simplified outline of the approach taken by a behavioral technologist whose objective is to cause an individual to "understand x," "know x," or "be able to do x."

1. He must first find an acceptable way of determining whether the individual "understands x," "knows x," "can do x."

2. He develops an operational way of specifying the conditions which will be accepted as evidence that the individual "understands x," "knows x," "can do x."

3. The specification of these conditions always involves the specification of BEHAVIOR. The specifications are met when the individual does or says certain things under certain conditions.

4. He brings about the conditions which he has specified by operating on the individual's BEHAVIOR in accordance with known principles of behavior theory (or learning theory). This may involve constructing a self-instructional program or devising a set of step-by-step instructions to be administered by a teacher.

5. When the individual, after completing the program of instruction, exhibits the specified behavior under the specified conditions, then, by definition, he "understands x," "knows x," "can do x."

It is important to note that the behavioral technologist, in practice, substitutes the term "behavior" for "knowledge" and "understanding." Within the class of "behavior" his categorizations include "discriminations," "generalizations," "concepts," "chains," and "schedules of reinforcement." The behavioral technologist argues that it is inconsequential whether "knowledge" is or is not basically behavior. The significant consideration is that the only tangible evidence of knowledge we ever have is behavioral evidence. The only way to determine whether an individual "knows" something is to see what he will say or do under certain conditions, as when we ask him a question and observe his answer. It might also be noted, in this connection, that the behavioral technologist regards verbal expression, whether spoken or written, as behavior (58). The principal support of this approach derives from its practical successes and its pragmatic utility.

The approach is sometimes thought to be oversimplified because it asserts that knowledge and understanding are "merely behavior." The behavioral analysis of knowledge, however, takes into account not only the behavior itself, but also the conditions under which the behavior occurs. Both the prevailing stimulus conditions and the prevailing behavioral contingencies (41) are considered. The behavioral analysis of knowledge also takes into account the history of the learner with respect to these stimulus conditions and behavioral contingencies. This approach offers a methodology for analyzing "complex mental processes" (51, 52, 54, 58).

To sum up, then, the behavioral technologist approaches a problem by following these steps:

1. He specifies the behavior which the student is to acquire (where behavior may be evidence of knowledge).

2. He specifies the relevant characteristics of the student, including the student's present level of knowledge.

3. He performs a behavioral analysis of the material to be taught. This involves "atomizing" the knowledge to be imparted according to learning theory principles. The knowledge is broken down into concepts, discriminations, generalizations, and chains.

4. He constructs a teaching system or program by which the behavior may be built into the student's repertoire. In constructing this system or program, he decides upon the techniques that are most suitable for the problem at hand.

5. He tests the teaching system on sample students, and revises it according to the results, until the desired result is reliably achieved in student after student.

When the training of larger groups or entire populations is involved, a somewhat different, though related approach is used. This will be discussed in Section VI under the heading of Manpower Development.

## IV. PROGRAMMED INSTRUCTION

The application of behavioral technology to the teaching of certain verbal and intellectual skills has come to be known as "programmed instruction." The four examples of programmed instruction presented below illustrate some of the main techniques, including concept formation (42, 60), science teaching that involves laboratory equipment, mathematical calculation (chains involving branching), and audio-lingual communication skills.

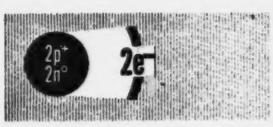
Each example is made up of a series of questions (called frames) and answers. The answer to a given frame follows it, so that the student can confirm his answer immediately.

### A. Examples

#### 1. Atomic Number

The first example of programmed instruction teaches the concept of atomic number (14). Note that the definition of atomic number is taught only after the underlying concept has been established. In frames 1, 2, and 3 the student is asked for the atomic number, given the number of protons in the nucleus. Frame 4 requires him to indicate the number of protons in the nucleus, given the atomic number. Only after the student has used the concept and applied it, is he asked to name the concept in frame 5.

**CHEMISTRY I Atomic structure and bonding**

| ANSWERS | QUESTIONS |
|---|---|
| | The number of protons in an atom is called the *atomic number* of that atom. The atom below has an atomic number of _____.   1 |

See answer on following page.

# CHEMISTRY I Atomic structure and bonding

ANSWERS

two

1

QUESTIONS

An atom has eight protons in its nucleus. What is its atomic number?

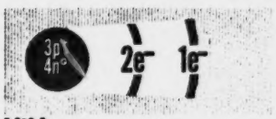
(See Answer)

2

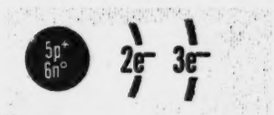
eight

2

What is the atomic number of the atoms below?




Lithium



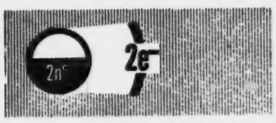

Boron

3

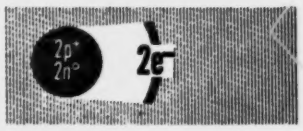
Lithium: 3
Boron: 5

3

This atom has an atomic number of two. Fill in the missing protons.




4




4

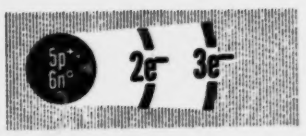
An atom has four protons. Its _____ is 4.

5

atomic number

5

Explain why the atomic number of this atom is 5.




6

This atom has five protons, therefore, its atomic number is five.

6

What do we mean by the term atomic number?

7

The number of protons in the nucleus of an atom is the atomic number of that atom.

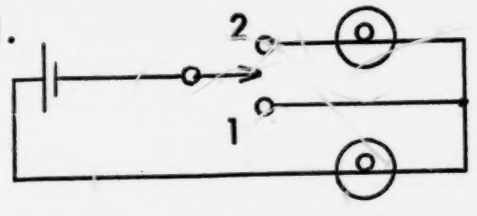
7

## 2. Ohm's Law

Among modern science educators, there is an increasing awareness of the need to teach the experimental and empirical bases of the laws and principles that are taught, in addition to the principles themselves.

In order to take the program from which the sample below is excerpted, the student must have in front of him a kit which includes electric batteries, light bulbs, a switch, and some wire. When the student has reached the point in the program where the sample begins, he has already learned some basic electrical concepts, but not Ohm's Law. Note how the frames progress from experimental manipulations of the equipment to specific observations which in turn lead to generalizations. The student arrives at the statement of Ohm's Law by generalizing from his own empirical observations. This is an instance of advancing from the concrete to the abstract in the teaching of concepts.

The student has just built a circuit according to instructions.

| QUESTIONS | ANSWERS |
|---|---|
| 211. Draw the circuit diagram of the circuit you just built. | 211.   |
| 212. Throw the switch to position 1, then to position 2.<br><br>What happens to the light bulbs in each case? | 212. In position 1, one bulb glows brightly. In position 2, both bulbs glow dimly. |
| 213. Suppose each light bulb has a resistance of 10 ohms. How much resistance would two light bulbs in series have? | 213. 20 ohms (10 ohms + 10 ohms = 20 ohms) |
| 214. How can you tell by looking at a bulb how much current is in it? | 214. The more current in it, the brighter it is. |

215.

Is a bulb brighter when the electrons go through both bulbs in series, or when they just go through one bulb?

215.

A bulb is brighter when the electrons just go through the one bulb.

216.

What can you conclude about the relationship between the number of light bulbs in series and the amount of current in the circuit?

216.

The more light bulbs, the less current or the fewer the light bulbs, the more current.

217.

What can you conclude about the relationship between the amount of resistance in the circuit and the amount of current?

217.

The more resistance in the circuit, the less current or the less resistance in the circuit, the more current.

218.

The ohm is the unit of _____

The ampere is the unit of _____

218.

resistance

current

219.

The more _____s in a circuit,
(name of unit)
the fewer _____s will flow.
(name of unit)

219

ohms

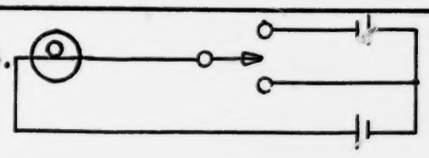
amperes

In frames 220 - 243 the student learns that voltages add when dry cells are placed in series, and that voltage is measured in volts. Then the student interchanges the light bulbs and dry cells in his circuit, and proceeds with the following frames:

244.

Draw the diagram of the circuit you just built.

244.



245.

In which circuit is there more voltage?

245.

in the one with two dry cells in series

246.

Try the switch in both positions. What do you observe?

246.

When the circuit has two dry cells in series, the bulb is brighter than when the circuit has only one dry cell.

247.

You observed that the bulb glowed more brightly when there were two dry cells in series. What does this tell you about the effect of voltage on current?

247.

The more voltage, the more current.

248.

What happened to the current when you increased the voltage?

It ☐increased
☐remained the same
☐decreased

248.

It increased.

249.

What happened to the current when you increased the resistance?

It ☐increased
☐remained the same
☐decreased

249.

It decreased.

250.

In your experiments you observed that

1. The higher the _____ the higher the current.
2. The higher the _____ the lower the current.

250.

voltage

resistance

251.

Write this in the form of an equation:

$$\text{Current} = \frac{(?)}{(?)}$$

251.

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

3. Squaring Numbers Ending in 5.

This example illustrates the teaching of a simple mathematical skill. While the process being taught is very simple, the technique applies in modified form to the teaching of more complex mathematical and problem-solving skills. The essence of the process is the "backward fading" of a reasoning chain. Note how the final members of the chain are "faded out" first. At the end, the student is required to perform the entire calculation without any support. Note also how the same basic reasoning process which the student learns is applied to a different problem in each frame of the program.

The example also illustrates one important "branching" technique. The student is allowed to skip ahead to the end of the sequence as soon as he can prove that he has mastered the skill.

| QUESTIONS | ANSWERS |
|---|---|
| 1. Here is how you can multiply 45 x 45.<br><br>Between which two multiples of ten does 45 lie? Obviously 40 and 50.<br>Multiply these two numbers: 40 x ___ = 2000<br>Add 25 to the product: ___ + ___ = 2025 | 1. If you want to check this, multiply 45 x 45 the long way. |
| 2. Here is how you can multiply 75 x 75.<br><br>Between which two multiples of ten does 75 lie? 70 and ___<br>Multiply these two numbers: ___ x 80 = ___<br>Add 25 to the product: _____<br><br>From now until the end of the program, any time you feel that you can multiply 95 x 95, or 55 x 55 mentally, try the last question. Otherwise, go on to the next question. | 2. Your Answer Should Be 5625 |
| 3. Here is how you can multiply 35 x 35. Do the steps mentally.<br><br>Between which two multiples of 10 does 35 lie? ___ and 40<br>Multiply these .... _____<br>Add 25 .... _____ | 3. Your Answer Should Be 1225 |

4. Here is how you can multiply 85 x 85. Do the steps mentally.

Between which two multiples of 10 ....
____ and ____
Multiply .... _____
..... _____

4. Your Answer Should Be 7225

5. Here is how you can multiply 15 x 15. Do the steps mentally.

Between which .... _____
..... _____
..... _____

5. Your Answer Should Be 225

6. Multiply 65 x 65 mentally

Multiply 95 x 95 mentally

Multiply 55 x 55 mentally

6. ANSWER: 4225

ANSWER: 9025

ANSWER: 3025

4. Listening

This example cannot be reproduced here because it is presented to the student on magnetic tape. The program is designed to teach effective listening. The program consists of a series of episodes, each of which presents the student with a listening problem. The problems become gradually more complex. In the first frame of the program the student hears a voice saying "We can't use this cutter because the blade is too long." The narrator then says "In your answer book, write the reason the speaker gave for why he couldn't use the cutter." After the student has had time to write the answer, the narrator tells him the correct answer. Each successive statement the student hears is somewhat longer and somewhat more complex. The statements are made in different voices and different accents. The speakers become more and more digressive and discursive, more rambling and more emotional. The student's task is always to summarize the statements that are being made by the speakers, and to isolate the critical content. Early in the program the student writes down his summaries so that he can easily check them. As he progresses, he gives oral summaries with increasing frequency. At the end of the program the student is able to summarize rambling, five-minute-long speeches in terms of the main points and the supporting arguments. This type of program is typical of programs currently being used to teach various communication skills.

It is evident that a variety of techniques are used in the above applications. However, they all apply learning theory in a systematic way, and have certain features in common (11):

B. Characteristics of Programmed Instruction

1. Small Steps

Each question builds new knowledge on the material just mastered. The student advances to more difficult and complex material only when he is prepared, in a series of small, controlled steps suitable to his particular level of knowledge. It is important, in this connection, to make the distinction between the size of the step and the size of the unit of behavior being required. The student may be required to write out a mathematical proof covering an entire page, and yet this performance may only represent a small step, i.e., a small advance over his previous level of knowledge; conversely, the student may be required to fill in only a single word, and yet this could represent a very large step for him.

2. Active Response

Every question requires the student to make an active response. Rather than being the passive recipient of information which he may register briefly and then forget, the

student is always actively exercising the knowledge which he is acquiring. Each response the student makes brings him one step closer to the knowledge or skill which is being established. The step by step requirement of active response insures that the student give careful attention to the significant content of material presented in each frame.

3. Immediate Confirmation

As soon as the student has made his response, he is informed of what the answer should have been. The purpose of the immediate confirmation is to strengthen the behavior as it emerges, and, in case the student makes an error, to correct it before new knowledge is built on an erroneous foundation. Thus the student receives continual feedback while he is learning, not merely at the very end.

4. Low Error Rates

One of the findings of learning theory which programmed instruction incorporates is that learning is most efficient when the student makes few errors (25, 64). This may seem contrary to common sense, since normal everyday learning, trial and error learning, appears to depend upon the occurrence of errors. Research borne out by practical experience has shown, however, that errors become engrained to some degree, and accordingly interfere with the retention of correct behavior. A student can learn to avoid errors more efficiently by thoroughly learning the correct behavior than by actually making the errors and "learning from them." Programs are accordingly designed to minimize errors.

5. Self-Pacing

When a group of individuals learns by programmed instruction, each individual advances at his own best rate. This feature of programmed instruction is frequently cited as one of its advantages, because it translates individual differences into different learning rates rather than different failure rates (10, 27).

6. Operationally Defined Objectives

A significant characteristic of programmed instruction is its orientation toward a specific and specified set of terminal behavior objectives. As was pointed out earlier, any application of behavioral technology involves the operational definition of the desired behavioral outcome. The development of an instructional program begins with the specification of the terminal behavior objectives. These specifications often take the form of a comprehensive final examination. The program itself provides the means for achieving these specified objectives.

## C. Techniques of Programming

### 1. The Response Mode

The form which the response takes, whether it is written, oral, manipulative, a choice response, a long response or a short one, depends entirely upon the behavior being taught. There is no theoretical limitation upon the form or mode of the response. On the contrary, learning theory demands that each response take the student one step closer to the terminal behavior being established, whatever the behavior may be and therefore that the response mode used within the program be the same as the response mode called for in the terminal behavior specifications (42).

Learning theory demands that a program in mathematics require the student to work out examples, to solve problems, and to devise and present proofs and derivations; that a program on typing require typing behavior on a typewriter; that a program on welding require the student to weld with real welding equipment; and that a program on language require spoken responses to auditory stimuli. Science programs would require laboratory equipment, at least for the practical parts of the course. Programs in the area of communication skills would require the student to make the appropriate statement or utterance in response to a taped episode.

A frequent defect of inexpert programs is an inappropriate selection of response mode. Programs which confine the student entirely to multiple choice responses or to one- or two-word responses to be written into blanks should not be expected to generate significant skills other than choosing alternatives or writing words into blanks. Many commercial programs which do restrict the response mode in this manner do so because of constraints imposed by the design characteristics of teaching machines which the company may be marketing simultaneously with the programs, or because of inadequate behavioral analysis. These problems are discussed in greater detail further on.

### 2. Branching Techniques

Some of the principal branching techniques currently in use are described below. The term "linear" is commonly applied to program segments having no branching points (6).

#### a. Diagnostic Frames

The student is instructed as follows: "If you can answer this question correctly, proceed to frame x," or "If you had difficulty with this question, go to the remedial section on page y."

b. "Express Stops"

The student is instructed, "Try this frame. If you get the right answer, skip ahead to frame x. If you get the wrong answer, proceed to the next frame." (See the example of this on pp. 10 - 11.)

c. Graded Entry Points

The student enters the program at a point which depends upon his level of preparation.

d. "Intrinsic" Programming

This technique applies only to the multiple choice response mode. If the student chooses an incorrect alternative, he is directed to a remedial paragraph which attempts to explain the probable source of his error to him, and directs him to try the multiple choice item again. This cycle is repeated until the student chooses the correct alternative (13).

## V. HOW A PROGRAM IS DEVELOPED

### A. Staffing and Economics

The development of a program is a complex production problem requiring a team effort by individuals with a variety of skills. The main skill categories are:

1. Subject matter experts who are competent to specify content and objectives.
2. Behavior analysts who analyze the knowledge in accordance with learning theory principles.
3. Programmers who develop frame sequences on the basis of the behavioral analysis.
4. Project administrators skilled in scheduling and coordination.
5. Test subjects who are representative members of the target population, on whom the frame sequences are tested as they are written.
6. Program editors who can revise, refine, and generally edit the programmers' work.
7. Typists, draftsmen, and illustrators who bring the crude manuscript into publishable form.

A useful statistic relating to production costs is that it takes about 100 man-hours of labor on the part of personnel from categories 2, 3 and 6 above, to produce one hour of programmed instruction. While this is an average figure, it allows one to make rough estimates of the costs of programmed instruction. Factors affecting costs will be discussed further on.

The following is a more detailed phase-by-phase description of the program production process.

B. Phase 1. The Specification of Objectives (Task Analysis)

As was explained earlier, the application of behavioral technology to a training problem requires an objective and operational specification of the performance goals to be attained. This specification must state the conditions that will be accepted as evidence that the trainee "understands x," "knows x," "can do x." In practice, this specification looks very much like an examination which the trainee might take, or an applied performance test. It differs from most examinations in that it is much more comprehensive: It tests not merely a sample of the behavior to be established; it tests all of it (24).

Also, it is not merely a set of questions; it is a set of questions with the corresponding set of answers. It may be compared to the performance specifications of a piece of electronic equipment.

Before the program development process can be initiated, some other specifications are required as well. One of these is the specification of the "target population."

This is a description of the student group for whom the program is intended. In practice, the "target population specification" is not nearly as critical as the specification of terminal behavior. The target population specification becomes important during the testing phase (Phase 3), during which the target population must be simulated in order to carry out the developmental tests. A third specification which is required is the initial level of knowledge of the target population. Just as the terminal knowledge must be specified, so must the initial knowledge be specified. The program of instruction may be thought of as a bridge from the initial knowledge to the terminal knowledge.

As was stated above, the terminal knowledge specification usually takes the form of a comprehensive final examination. It is used as the measuring instrument for determining the extent to which the educational objectives of the program have been met. Although it is sometimes called the "terminal behavior test," it is not a test in the usual sense. First of all, it is not necessarily written. It may be an oral test or a performance test. Secondly, it is usually not "objective." Except in rare cases, it consists of essay, or "long answer" items, rather than multiple choice or "short answer" items. Finally, it is not used primarily as a test. During program development, it is used as a specification of objectives against which the programmers may check the adequacy of their frames. After the program is finished, it is used as the specification which communicates to the prospective user what behavior or knowledge the program will impart.

C. Phase 2. Behavioral Analysis

Once the behavioral objectives have been adequately specified, a psychologist trained in behavioral analysis can examine the behavior in question and break it down into its elements. He generates a "catalogue of behavior" which lists and specifies all the "discriminations," "generalizations," "concepts," and "chains" that are involved.

These categories are useful to psychologists concerned with establishing behavior because extensive research in learning has revealed how discriminations, generalizations, concepts and chains are learned most efficiently. While these categories are conceptually quite simple, they are broad enough that they encompass most of the behavior which is of concern to us in the teaching of knowledge and skills. These categories apply less well to the analysis of personality characteristics (42).

As was mentioned earlier, the experimental analysis of chaining, discrimination, generalization, and concept formation was carried forward by experimental psychologists, including Skinner, during the past 60 years (33). To psychologists, a chain is a sequence of alternating stimuli and responses where each response produces the stimulus for the next response. Common examples of chains are problem solving procedures, sequential decision processes, logical reasoning sequences such as explanations or proofs, memorization tasks, manual skills, and diagramming tasks (21). The behavioral analysis would specify the component members of these chains and the alternative choices at the decision points.

A concept is defined in terms of its instances, members and manifestations. Examples of concepts are "electricity," "dog," "linear equation," "commutativity." The behavioral analysis of a concept lists appropriate instances and non-instances. The non-instances would include cases which resemble the concept but do not belong in the same class. Capacitance, an example of a concept in physics, would be analyzed in terms of a set of experiments or physical phenomena in which capacitance manifests itself in observable form. Behavior theory defines a concept as "generalization within a class, and discrimination between that class and other classes" (33, 60).

Once the behavioral catalog is complete, the items in the catalog are sequenced in accordance with the principles of "response differentiation" (33). This involves analysis of the hierarchy of concepts, and the interweaving of concepts and chains. The resulting "flow chart" prescribes the progression of concepts and chains, and forms the basis for the final sequence of questions in the program.

D. Phase 3. Frame Writing and Testing

When the behavioral analysis is completed, three sets of documents are available: (1) the terminal behavior specifications, (2) the behavioral analysis, and (3) the detailed item sequence given by the flow chart. These three sets of documents are used by the frame writers to generate the frame sequences of the program. This is not to say that the subject-matter experts and psychologists no longer have a role. It is essential that they remain available for consultation. While the frame writers should ideally have some familiarity with the subject matter and with the principles of learning theory, they are generally not sufficiently expert to solve every subject matter problem that might arise.

The frame writers use the three documents cited above as the "blueprint" for the frame sequences. They make such decisions as which response to require at each step, how much material to include in any given frame, which stimuli to use in order to elicit the desired response, and how large to make each step. The frame writers must insure by the design of their frames that the student is responding to the intended stimuli, rather than to extraneous, unintended stimuli (39, 40). They test the frames they write on members of the target population. The feedback they obtain from these tests is the basis for revising the program so that it will teach better the next time it is tested (7, 10, 25). Testing and revision cycles are continued until the program works satisfactorily. A program normally goes through two to four testing and revision cycles before this is achieved. If the terminal behavior specifications demand that members of the target population achieve a median score of 90% or better on the test, the program is revised until this criterion is reached.

The programmer's set of skills can generally be mastered by a suitably gifted individual after two to six months of practical experience. The skill of the behavior analyst, on the other hand, is another matter. A successful behavior analyst not only needs a good knowledge of learning theory, but must also have experience in taking complex verbal and other behavior, and breaking it down into its component chains, discriminations, generalizations, and concepts.

Probably the chief reason for the scarcity of competent experts in the field of behavioral technology and programmed instruction is the scarcity of good learning theorists with sufficient practical experience in behavioral analysis.

It should be noted that the method of program production described here is the most advanced state of the art, as practiced by professional programming groups. Numerous programs have been and are still being produced by much more casual procedures. The method by which a given program was produced can generally be deduced from the program's characteristics. For instance, failure to specify terminal behavior precisely results in a drifting program, which appears to place excessive emphasis on insignificant details. From the teacher's standpoint, such a program produces uncontrolled

and unknown effects on the student's knowledge. The student will often call such a program "boring." Equally serious is the omission of behavioral analysis during program development. The most usual and most visible sign of inadequate behavioral analysis is excessive verbiage, drawn-out sequences in which obvious points are belabored excessively, emphasis on eliciting the right words at the expense of conceptual understanding, lack of examples and illustrations when they are needed and a preponderance of trivial responses. Since behavioral analysis is the means of identifying the pedagogic problems of the subject matter, to omit it is to omit the application of learning theory. Many of the criticisms which knowledgeable educators have raised against programmed instruction have been leveled at programs written without adequate behavioral analysis, usually by non-psychologists.

E. The Economics of Program Production

In considering the costs of developing programmed instructional materials, it is useful to separate the cost of performing the task analysis and generating the terminal behavior specifications from the costs of producing the actual program. This separation is useful because the cost of generating the terminal behavior specifications varies a great deal more from one problem to the next than does the cost of producing the program itself.

The cost estimates given below are based on the experience of several American companies that produce programs.

An efficiently functioning programming group can produce programmed material for $1,000 to $3,000 per hour of instruction. These costs include behavioral analysis, writing the first draft of the program, testing and revising this draft as many times as is necessary to meet terminal behavior specifications, and manufacturing the final copy. There are several possible reasons for variation in the costs within the limits given above: (1) complexity and degree of specialization of the subject matter; (2) salary requirements of programmers who have sufficient familiarity with the subject matter; (3) availability of target population members to serve as test subjects for developmental testing of the program; and (4) production costs.

The costs of performing the task analysis and of developing the terminal behavior specifications can vary from zero, as when the specifications are already in existence, to $3,000 per hour of instruction, as when a highly complex and technical subject matter must be researched, checked with specialists and consultants, and matched to the requirements of the ultimate target population. An example is the development of syllabi suitable for post-graduate medical education of practicing physicians.

## VI. APPLICATIONS OF BEHAVIORAL TECHNOLOGY TO MANPOWER DEVELOPMENT

The term "manpower development" is generally applied to large-scale training projects whose objective is to meet the manpower needs of a country, region, or industry. Whether the objectives of the manpower development project are economic, industrial, or military, the training always cuts across a variety of jobs and skills.

Every society has groups that are not adequately reached by its educational institutions. For instance the mentally retarded, the gifted, migrant laborers, immigrants, adult illiterates, school dropouts, and displaced workers are groups which are generally not able to profit from the society's main institutions. They form the residual categories, and as such, are frequently neglected. They are difficult to reach for a number of reasons:

A. They are difficult to identify and assemble as groups.

B. Being on the cultural fringes of the society, they are often poorly motivated to conform to its educational demands.

C. They may have status problems which they are handling in ways that are incompatible with educational conformity (8).

D. They may lack the fundamental verbal and social skills that are prerequisite for profiting from existing educational institutions. For instance, they may be poor readers, may not know arithmetic, or may lack study habits. For such reasons, locally sponsored programs which offer "more of the same" in educational remediation and special services, usually fail.

E. They may be distributed in "pockets" separated by cultural, social, state, institutional, regional, or other lines. Thus it is difficult for local agencies whose scope is limited, to justify the investment required to develop adequate educational programs.

These problems are aggravated in a developing region, particularly one undergoing industrialization (9). When the rate of technological innovation increases, the displacement of workers also increases, literacy becomes more important, and because teachers tend to drift into administrative and technical jobs, the teacher shortage becomes more acute. Economic development places new strains on available manpower resources and on the society's ability to train and retrain.

Behavioral technology offers some answers to problems B, C, D and E enumerated above: By providing immediate confirmation at each step and insuring that the student maintains a continuous sense of learning and achieving, a good instructional program overcomes the motivational problem to a considerable extent. The status problems of fringe groups in the classroom derive from two main causes: (1) unfavorable comparison with other students who have fewer learning problems, and (2) failure to get along with the teacher who is likely to represent a different sub-culture. Programmed instruction eliminates these problems by eliminating the conventional classroom setting.

For students who lack fundamental verbal, reading, or arithmetic skills, instructional programs may be individualized, by means of graded entry sub-routines (see section IV C 2). Defective study habits become less significant if the steps of the program are sufficiently small, if active participation is required, and if adequate review is built into the curriculum.

Another way in which instructional programs can mitigate the problems of training marginal groups arises from the fact that objective measures of progress become available on a fine-grain level, and on an individualized basis, as educational objectives are fulfilled. These conditions permit the effective use of "extrinsic" incentives for learning to be tied to achievement at frequent intervals during training. Such incentives may be monetary, advancement or promotion, access to privileges or special credits which can be exchanged for more generalized rewards in another environment. In this way, the awards which ordinarily depend upon long-term fulfillment can be provided during earlier portions of the training period, with more immediate effects on the motivation of trainees.

It is possible to distinguish between two basic types of manpower development problems: (1) There are jobs that need to be filled and an insufficient trained manpower pool from which to fill them; and (2) There is a group of individuals for whom there are insufficient jobs. The two problems frequently co-exist side by side, in the same society and region. Progressive industrialization of a region or society invariably makes demands upon available manpower resources that cannot be fulfilled. Thus, the most general formulation of the manpower development problem is the training of unemployed or underemployed individuals for unfilled jobs. This formulation does not by any means ignore the fact that in many cases the most efficient general-purpose manpower strategy is the development of fundamental verbal, scientific and technical skills that constitute the core curriculum for a broad range of specializations.

Behavioral technology suggests the following general approach to any manpower development problem:

A. The jobs which are to be filled are described and categorized. These descriptions must take the form of specifications of the behavior which men must possess in order to fill the jobs. The correct way to arrive at these descriptions is to analyze the performance and skill profiles of individuals who are already filling the jobs successfully. A complete and useful characterization of a job includes the required ancillary repertoire, such as knowledge of arithmetic, reading, writing, and other verbal skills. Specific administrative and managerial skills may be important in this specification.

B. The population which is to be trained for these jobs is described and categorized. These descriptions and categorizations must take the form of specifications of the behavioral repertoires (skills, knowledge, educational achievement, etc.) of these individuals before any training programs have been administered.

C. The set of skills required for each job is separated into two subsets: those that can economically be made self-instructional, and those that are best taught on the job. The objective is to maximize the proportion of training which is made self-instructional.

D. The members of the population to be trained are grouped into more homogenous subgroups according to their educational and skill profiles in such a way as to minimize the total amount of training time that will be required to train the men for the jobs. Matching up the prospective trainees with the jobs they will fill requires the consideration of many factors, including geographic factors, personal and occupational goals, and relative time urgencies in filling different types of jobs.

E. The specifications of the jobs to be filled are analyzed in terms of their behavioral components. This is the same behavioral analysis that was described earlier in Section V C, "How a Program Is Developed, Phase 2."

F. A set of self-instructional programs to teach the subset of skills that need not be taught on the job is developed. These teaching programs are designed to bridge the gap between the initial behavioral repertoires of the trainees and the behavioral repertoires required to fill the jobs successfully. Again, the program production process involved is the same as that described in Section V D, "How a Program Is Developed, Phase 3."

G. The appropriate programs are administered to the appropriate trainees. The trainees may complete the programs while still employed in their present jobs, either during work breaks, on their own time at home, or in specially provided classrooms. Alternatively, the programs may be administered in a centralized training location. The mechanics of administration depend upon the economic and administrative constraints of the project.

H. The trainees are placed in their jobs as soon as they have completed their training programs. After the required on-the-job training is completed, their performance is studied and evaluated. If any deficiencies are found in their repertoires of skills, these deficiencies are corrected by the development of additional programs, or by additional on-the-job training, whichever is required.

While these are the broadest outlines of a manpower development program, actual implementation and installation entails many additional problems. Some of these additional problems are summarized below.

1. The recruitment of candidates for training or retraining involves more than merely considering which individuals have the closest approximation to the knowledge and skill to be taught. Motivational factors, for example, must be considered. This involves determining personal and occupational goals of the trainees, and ascertaining the types of incentives which are most effective. The determination of effective incentives is important not only so that these may be employed during the training process, but also so that they may be built into the eventual work environment.

2. When training is decentralized, as it often is, special follow-through procedures must be instituted. Among these is the use of trained cadre groups, together with specially designed reporting procedures. Special programs which are administered on an emergency, crash, or service basis, often employ people unskilled in the subject-area in which training is offered. The use of volunteers in such efforts is common. Programmed instruction can

play a significant role in the reduction of variability in the quality of training imparted by such middlemen. What is required, however, is the calibration of the training effects of such materials, together with guidelines for their use, and the incorporation of such information into administrative manuals which accompany the programs. These steps, together with some training of the personnel who will implement the programs, can aid in the successful dissemination of the training without significantly weakening its effectiveness.

3. When training is conducted at a centralized location, significant problems arise as a consequence of different rates of progress. This raises incentive problems and problems of logistics, such as making sure that every trainee has all the training materials for which he is ready, and transporting the trainees to the jobs for which they have been trained as soon as the training is completed.

4. The design of training systems in a broad manpower effort requires the determination of the appropriate "mix" of a number of components. Major alternatives are:

   a. Training for immediate job placement. Here available employment opportunities are surveyed with a view to filling as many jobs as possible with the minimal amount of training.

   b. Training for long-run placement. The jobs identified in a. may be disappearing from the economy or may have little potential for further mobility. To meet this problem, long-term projections based upon economic and industrial forecasts must be studied to identify skills for which the demand will be increasing rather than decreasing, so that the appropriate training component can be added to the program.

   c. Remedial training. For certain segments of the population, neither a. nor b. may be possible without extensive remediation in basic literacy skills and "study habit" skills.

   d. Professional preparation. In the most marginal groups, there is an important minority who are candidates for professional education. The identification and development of such groups through programs of testing and scholarships are likely to be of critical importance in areas undergoing rapid development, where the accelerating demand for professional and technical personnel cannot be fulfilled by "normal" growth.

   e. Public works. Public works programs normally have aims other than education or training. Yet they are instituted under the same circumstances which call for the four components listed above, and form part of the context in which policy is made. Though the training component may be minimal, it must be assessed and met. Furthermore, there usually exists a relationship between the recruitment and staffing problems of public works programs and the chronic problems of training that exist in the same locality. This relationship must be considered in the over-all design of any manpower program.

The success of any manpower development project depends principally upon the adequacy with which steps A (description and categorization of the jobs which are to be filled) and E (behavioral analysis of the specifications of the jobs to be filled) are carried out. These are the steps which make the heaviest demands upon behavioral technology. During the coming year, major methodological refinements may be expected to emerge from such projects as the one currently being carried out in New York City jointly by Basic Systems Incorporated and the Vocational Service Center of the New York YMCA, which will provide vocational and remedial training to school-dropout populations, under contract with the U.S. Office of Manpower, Automation, and Training, as provided by the Manpower Development and Training Act.

## VII. CURRENT ACTIVITY IN THE FIELD

### A. Programmed Instruction in Industry

It is safe to say that most of the largest American corporations are now using programmed instruction to some extent. The very largest corporations, including AT&T, IBM, Equitable Life Assurance Society, DuPont, Univac, Raytheon, Dow Chemical, Monsanto Chemical, Charles Pfizer, and at least one hundred others, have departments consisting of anywhere from two to fifty individuals whose special responsibility is programmed instruction. A number of national industrial organizations and trade associations also have special programmed instruction departments.

Some of the areas of training in which industry has found applications for programmed instruction are:

1. The Training of Plant Operations and Maintenance Personnel (35, 47, 69)

   Example: In the Engineering Services Department at E. I. DuPont de Nemours in Wilmington, Delaware, a series of programs to train plant personnel is being installed and made available to other plants. Among these programs are Reading Engineering Drawings, Measurement for Installation and Construction Skills, Plain Bearings, Liquid Level Measurement, Pressure and Its Measurement, Sheet Metal Layout, Shop Mathematics and Arithmetic, Positive Displacement Pumps, Temperature and Its Measurement, Mechanical Seals, Anti-Friction Bearings, Pipes and Fittings, Oxyacetylene Welding, Thermal Insulation, Principles of Lubrication, and Coupling Alignment.

   This massive utilization of programmed instruction at DuPont was supported by the outcome of DuPont's original experiment conducted in mid-1961. Two matched groups, each composed of thirty plant operator and maintenance personnel with 6th to 8th grade reading and mathematical skills, were assembled. One group was taught by a skilled instructor in the conventional classroom setting, and the other group was taught by programmed instruction. The results were as follows:

| | Programmed Instruction Group | Classroom Group |
|---|---|---|
| Average final examination score | 91.0% | 81.0% |
| Range | 87.2 - 97.6 % | 72.0 - 94.0 % |
| Average study time | 12.8 hours | 17.0 hours |
| Range | 11.5 - 15.3 hours | 17.0 - 17.0 hours |
| Average retention test score (retention test was given 18 months after the original test) | 84.0% | 73.0% |

To date, DuPont has trained approximately 3,000 men with this program. According to DuPont, a saving of $30 per trained man results from the reduction of training time and the elimination of the requirement for an instructor (69). Different versions of DuPont's experiment have been carried out by other companies in the chemical processing, food processing, auto manufacturing, and petrochemical industries, with comparable results (35).

2. The Training of Technical Sales Representatives

Example: At Pfizer Laboratories, as in many other drug companies, the professional sales representatives who sell drugs to physicians are trained by programmed instruction in the medical background of the products they sell. The programs are mailed out to the men wherever they may be and the men send the completed programs back to headquarters. Pfizer conducted an experiment over one year ago involving sales representatives who had previously been trained in the subject matter of Microbiology and Antibiotics by the conventional methods, consisting of classroom lectures, instructional pamphlets, and books. The men, divided into two groups, first took the final examination (terminal behavior specifications) for the program, Microbiology and Antibiotics. The test group was then given the program. Median completion time was 10.5 hours. Then both groups were given an alternate version of the final examination. The median scores were:

| | Control Group (75 men) | Test Group (64 men) |
|---|---|---|
| exam I | 54.0 % | 43.0 % |
| exam II | 56.0 % | 94.5 % |

Other versions of this experiment have been carried out at Pfizer and at many other large pharmaceutical companies, using programs in twelve to fifteen different medical subjects. The results are all about the same. To a company like Pfizer, the advantages of programmed instruction for sales training lie in the economics of training by correspondence. The frequency with which men need to be transported to a central location is reduced, and the levels of achievement can be controlled more closely, in spite of geographic dispersal (22).

3. The Training of Engineers (63)

Example: At Sperry Polaris, an experiment was conducted to compare the effectiveness of a first rate instructor, equipped with audio-visual teaching aids, to the effectiveness of programmed instruction. Each group contained ten engineers. One group was given the standard 20-hour course on the optical alignment system of the Polaris submarine. The course consisted of lecture, discussion, audio-visual demonstrations, and homework assignments. The other group was confined to the programmed textbook and was allowed no interaction with any instructor. Both groups were given the same comprehensive final examination. The two groups did about equally well, both scoring close to 90% on the examination. However, the group which studied by programmed instruction took an average of 20% less time to complete the course. The men in that group averaged about 16 hours of study time. From Sperry's point of view, this is a very successful outcome, since it demonstrates that the desired level of achievement can be attained without an instructor.

4. The Training of Computer Programmers (29)

Example: IBM conducted an experiment in 1960, to compare the effectiveness of programmed instruction and conventional instruction in teaching computer programming. The group taught by programmed instruction contained 70 men, and the group taught by the conventional lecture-discussion method contained 42 men. The men in both groups had an average of about 5 years of computer programming experience. The groups were also matched on the basis of a programmer-aptitude test. The subject matter taught in the experiment was the programming of the IBM 7070 computer. The group taught by programmed textbook achieved a final examination score of 94.7%. The control group scored 86.9%. The difference was statistically significant. As regards study time, the two groups took 11 and 15 hours respectively. Thus, the programmed instruction group took 27% less time.

This experiment and some others conducted since that time have encouraged IBM, Univac, Burroughs, and other computer companies to adopt programmed instruction for many aspects of programmer training. Univac, for instance, has just mailed out a 50-hour programmed text to teach customers the use of the Univac 1004 Card processor. By means of this program, Univac is attempting to make its customers more self-sufficient in using its machine. Shell Oil Company trained a group of computer programmers to write computer programs using the computer language

known as COBOL-1961. The trainees achieved an average score of 93.9% on the final examination (4). This same programmed text is being used in the U.S. Department of Defense.

5. Teaching Communication Skills

While no formal controlled comparison experiments are yet available in this area, a few programs of this type are already in successful use. American Telephone and Telegraph Company, for example, is using a programmed course to train telephone repair clerks. These clerks have the job of answering telephone calls from individuals whose telephone is out of order. Their task is to obtain all relevant information needed to service the customer. They must be trained to probe systematically, skillfully, and efficiently, and to remain courteous even when the customer is abusive. The programmed course has an audio-lingual, as well as a written, part. The audio-lingual part simulates the clerk's job situation.

The program on Effective Listening described on page 12 is in use in several dozen companies, including Pfizer, Dow Chemical, Caterpillar Tractor, AT&T, and General Motors. These companies use the program to improve the communication skills of their salesmen and managerial personnel. Currently under development are other audio-lingual programs to teach managerial skills, like interviewing and performance reviewing, and sales skills.

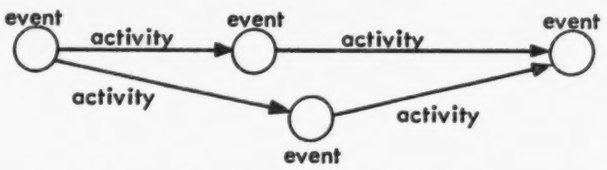
The Graduate School of Business Administration of the University of Michigan has established The Center for Programmed Learning for Business to disseminate, through seminars and workshops, information about applications of behavioral technology in industry. The objectives of the center are: to prepare participants to advise management on the use of programmed instruction in their organization, to prepare participants to evaluate and select outside commercial services, and to prepare participants to initiate the programming of selected topics, if this is found to be economically feasible.

The activities of this center testify to the increasing recognition in industry of the importance of thorough task analysis and adequate installation methods in the implementation of training programs.

B. Programmed Instruction for Training in the Military

By far the most significant use of programmed instruction in military training has been made by the Air Training Command of the U.S. Air Force. According to a recent report by Gabriel Ofiesh (44), the U.S. Air Force already has over 100 programmed courses. The reported savings in training time have ranged from 20 to 50% over conventional methods of instruction, and the levels of achievement are higher than any that had previously been achieved. The other military services are also using programmed instruction on an increasing scale.

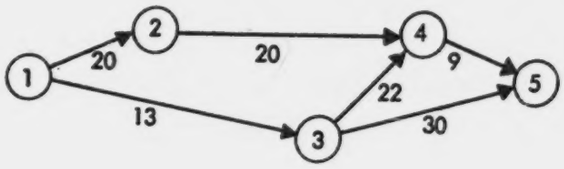
The short sample on the following page is the beginning of a program being used in the military as well as in industry. It teaches a project scheduling technique known as PERT.

| QUESTIONS | ANSWERS |
|---|---|
| 1<br>The last four years have seen an explosive growth of managerial methods for planning and control of complex projects.<br>_rogram _valuation _eview _echnique is the best known of these. | Program Evaluation Review Technique |
| 2<br>The managerial technique known as _ _ _ _ proved instrumental in completing the initial Polaris project well ahead of schedule. | P E R T |
| 3<br>PERT is used for the scheduling of events and activities.<br>Start production is an event<br>Production is an activity<br>Motor test ended is an event<br>Testing the motor is an activity<br>Termination of negotiation is an ( ☐ event ☐ activity )<br>Data analysis is an ( ☐ event ☐ activity )<br>Begin testing is an ( ☐ event ☐ activity )<br>Transport equipment to new location is an ( ☐ event ☐ activity ) | ☑ event ☐ activity<br>☐ event ☑ activity<br>☑ event ☐ activity<br>☐ event ☑ activity |
| 4<br>  <br><br>The circles in this PERT network refer to _____ s.<br>The arrows in this PERT network refer to _____ s. | events<br>activities |
| 5<br>Activities occupy time.<br>Events do not o cupy time; they are considered instantaneous.<br>"Start testing" ( ☐ does ☐ does not ) take time<br>"Negotiate" ( ☐ does ☐ does not ) take time<br>"End prototype production" ( ☐ does ☐ does not ) take time<br>"Recruit project members" ( ☐ does ☐ does not ) take time | ☐ does ☑ does not<br>☑ does ☐ does not<br>☐ does ☑ does not<br>☑ does ☐ does not |

QUESTIONS

ANSWERS

6




The numbers in the circles refer to _____s, which do not occupy any _____.

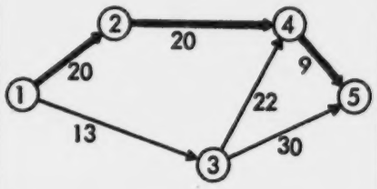
_____s occupy time. The numbers next to the arrows refer to the number of weeks taken up by the _____s which the arrows represent.

How many weeks would it take to complete path ①→③→⑤ ? (add them up) _____ weeks.

How many weeks would it take to complete path ①→③→④→⑤ ? _____ weeks

Which is the longest path you can find in the diagram? _____ weeks.

The longest path is called the critical path. Darken the critical path in the diagram.




events
time

activities

activities

43

44

49

C. The Development of Educational Programs for the Schools

American schools and colleges are currently using programmed instruction on an experimental basis in several thousand classrooms. Teachers generally use programs as supplementary instructional material, as remedial or background instruction for students who lack adequate preparation in some aspect of the prerequisites for the course, or for students who can profit from special enrichment.

Programs may be administered in any of several ways. They may be assigned for homework, or classroom time may be set aside for self-instruction. Under the latter arrangement, the teacher may hold conference sessions with individual students while other students work on their programs.

Programmed instruction has matured far more rapidly in industry than in the schools. By and large, the programs used in industry are superior to the programs being used in the classrooms. This is due to the fact that industry has obtained most of its programs from experts. Unlike the schools, industry has the funds to purchase the services of the leading commercial programming companies, and even to hire its own experts. The schools, on the other hand, are dependent upon what the open market offers. Most American publishers, in attempting to satisfy the imminent demand for programs, have tried to procure programs by the same methods they use to procure textbook manuscripts: by making a contract with a university teacher. Since an individual cannot produce a program of high quality without adequate financial and technical backup, the results have generally been disappointing. Programs of high quality for the schools will doubtless begin to appear when the market demand has become sufficiently strong to justify the type of financial investment currently being made in industrial programming.

In schools where programs are being tried out, considerable variations in effectiveness are reported (67). These variations may be interpreted in the light of the following trends:

1. Programs are currently gaining widest acceptance in the junior high school and high school grade range, and in science and mathematics areas. This trend reflects the relative ease of gaining consensus as to worthwhile teaching goals in these areas.

2. Although some very long programs have been produced, current activity favors the short unit devoted to a basic topic which can be flexibly assigned. This preference may be in part due to the administrative simplicity of installing a 5- to 15-hour unit within a pre-structured course, and in part to the desire for caution on the part of teachers.

3. The large majority of work is being carried out with the programmed text format, as opposed to programs in machines.

4. Consonant with the trend in 2. and 3. is the use of programs as homework, at least at the junior high and high school level. For younger students—in the fifth and sixth grades, for example—programs are used under supervised study conditions in the classroom. The logistics of this mode of use can interfere with other activities in the classroom. Schools of the future may have self-study carrels or study rooms designed into them, so that given assignments can be completed at the student's own pace between classroom discussions, laboratory exercises, and conferences (46, 66).

5. Most use of self-instructional programs is still on a trial, pilot project basis. This fact reflects more than the newness of the field and the uneven quality of available programs. It also reflects unsolved problems of educational administration. For example, many schools now experimenting with programs for "remedial" or "enrichment" purposes are using the same program for both purposes, although clearly the students involved in the two groups are very different. The decision springs not from a clear identification of the appropriate target population, but from a wish to leave the "main stream" of scheduled classroom instruction undisturbed. Programs are used only where they fit in most easily, where student time is unscheduled.

While the literature on the use of programmed instruction in the schools is by now very large, not one of the studies reported in the literature stands up under close scrutiny as a valid demonstration of the superiority of programmed instruction over conventional instruction. The studies are invalidated by serious flaws in experimental design, by the presence of contaminating variables, or by poor reporting. If one wishes to find support for the use of programmed instruction in the schools, it is easier to find such support in the experiences of industry than in the experiences of the schools (36).

D. Programmed Instruction for Post-Graduate Medical Education

One of the most serious problems faced by the practicing physician is that of keeping up with new advances in medicine. Recently, Pfizer Laboratories offered doctors a five-hour programmed text on Allergy and Hypersensitivity (1). At the time of writing, close to one out of every three doctors in the country has written to Pfizer requesting a copy of the program. This is strong evidence that programmed instruction can fulfill a need for practicing physicians. Below is a short sequence of frames from an electrocardiography program. It is included here to illustrate the greater complexity and larger step size which characterize physician programs, and the type of approach that can be taken in the teaching of diagnostic skills. While the sample below only teaches the doctor to determine whether a lead I tracing shows myocardial ischemia, injury, infarction, or some combination of these, it still illustrates, albeit in simplified form, an approach that is currently being used in other areas of medical education. The behavioral analysis underlying the construction of this frame sequence is discussed in Science Teaching and Behavioral Technology (42).

Do not look at answer (directly below) until you have completed Frame 1.

1 *The diagram below, taken from the Lead 1 tracing of a normal subject, shows the standard deflections of the electrocardiogram.*

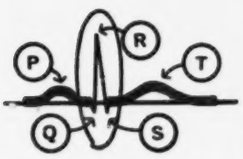
Label the five deflections, using the conventional letters P, Q, R, S, and T:

Circle the QRS complex.

The T wave is ☐ positive ☐ negative

see answer

1



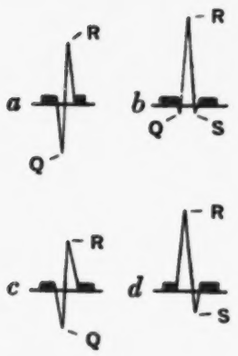

positive

2 *The Q, R, and S waves are defined as follows:*

*The Q wave is the negative (downward) deflection which initiates the QRS complex.*
*The R wave is the positive (upward) deflection of the QRS complex.*
*The S wave is the negative deflection immediately following the R wave.*

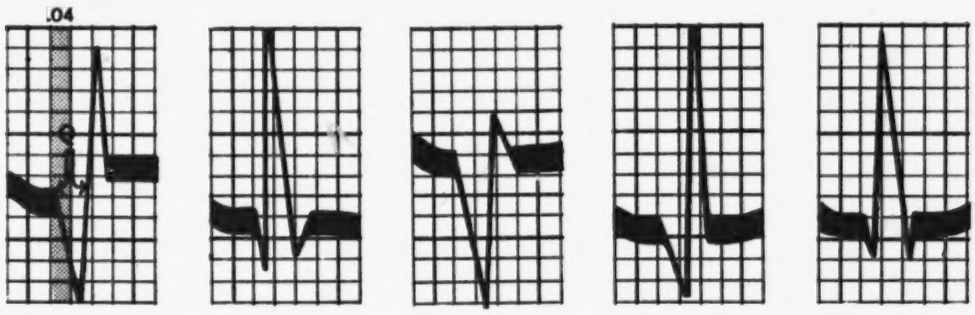
In each QRS complex below, label the Q, R, and S waves if they are present:

2




3 *A Q wave wider than one standard division, i.e., longer than 0.04 seconds in duration, is considered abnormal.*

Under each diagram, indicate whether the Q wave is normal or abnormal:




| ☐ normal ☐ abnormal | ☐ normal ☐ abnormal | ☐ normal ☐ abnormal | ☐ normal ☐ abnormal | ☐ normal ☐ abnormal |
|---|---|---|---|---|
| *a* | *b* | *c* | *d* | *e* |

3

*a* abnormal
*b* normal
*c* abnormal
*d* abnormal
*e* normal

4

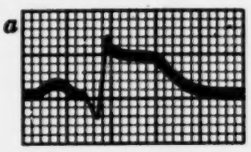
***The S-T segment begins at the end of the QRS complex and ends at the beginning of the T wave. An elevated S-T segment is abnormal.***

**For each diagram below, indicate whether the S-T segment is normal or abnormal.**

*a* **S-T segment elevated**

☐ normal
☐ abnormal

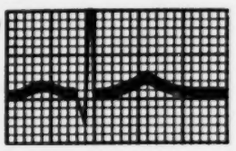
*a*



*b* **S-T segment isoelectric**

☐ normal
☐ abnormal

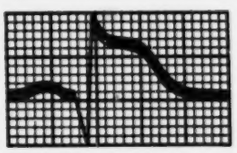
*b*



*c* **S-T segment** ☐ elevated ☐ isoelectric

☐ normal
☐ abnormal

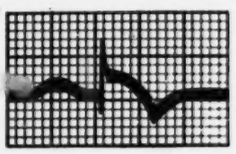
*c*



*d* **S-T segment** ☐ elevated ☐ isoelectric

☐ normal
☐ abnormal

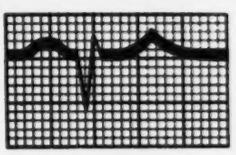
*d*



*e* **S-T segment** ☐ elevated ☐ isoelectric

☐ normal
☐ abnormal

*e*



4

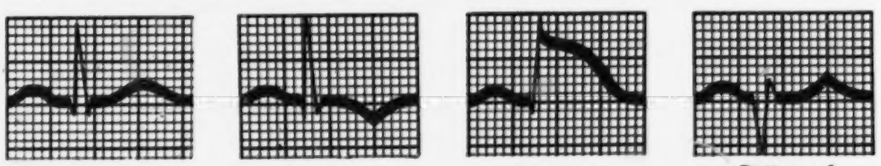
*a* abnormal
*b* normal
*c* elevated abnormal
*d* elevated abnormal
*e* isoelectric normal

5

**Referring to the diagrams in the panel below, check the correct box:**

*a.* An elevated S-T segment suggests . . . ☐ ischemia ☐ injury ☐ infarction.
*b.* A negative T wave suggests . . . . . ☐ ischemia ☐ injury ☐ infarction.
*c.* An abnormally wide Q wave suggests ☐ ischemia ☐ injury ☐ infarction.

***These diagrams show the ECG changes which, in various combinations, may be observed in myocardial infarction.***




5

*a* injury
*b* ischemia
*c* infarction

6

**Again referring to the above diagrams, check the correct box:**

*a.* The difference between the pattern of infarction and the normal pattern is the
☐ negative T wave ☐ elevated S-T segment ☐ abnormally wide Q wave

*b.* The difference between the pattern of injury and the normal pattern is the
☐ negative T wave ☐ elevated S-T segment ☐ abnormally wide Q wave

*c.* The difference between the pattern of ischemia and the normal pattern is the
☐ negative T wave ☐ elevated S-T segment ☐ abnormally wide Q wave

6

*a* abnormally wide Q wave

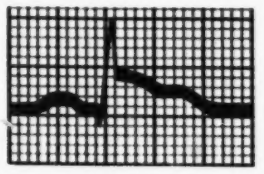
*b* elevated S-T segment

*c* negative T wave

7

The difference between this diagram and the normal pattern is the ☐ negative T wave ☐ elevated S-T segment ☐ abnormally wide Q wave

It suggests ☐ ischemia ☐ injury ☐ infarction



7

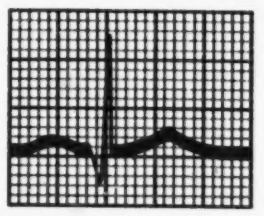
elevated S-T segment

injury

8

The difference between this diagram and the normal pattern is the ☐ negative T wave ☐ elevated S-T segment ☐ abnormally wide Q wave

It suggests ☐ ischemia ☐ injury ☐ infarction



8

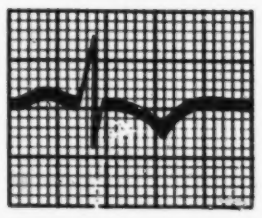
abnormally wide Q wave

infarction

9

The difference between this diagram and the normal pattern is the ☐ negative T wave ☐ elevated S-T segment ☐ abnormally wide Q wave

It suggests _____
(write in the answer)



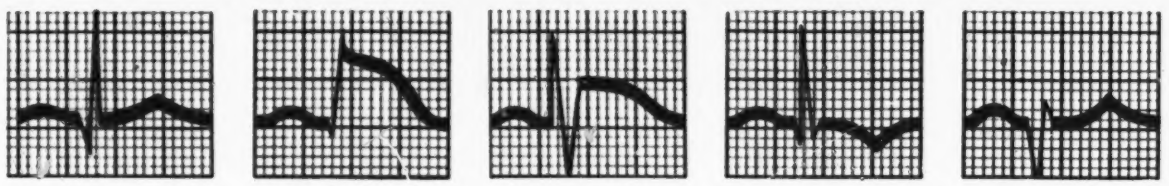
9

negative T wave

ischemia

10

Check the myocardial state suggested by each diagram:



☐ ischemia ☐ injury ☐ infarction *a*

☐ ischemia ☐ injury ☐ infarction *b*

☐ ischemia ☐ injury ☐ infarction *c*

☐ ischemia ☐ injury ☐ infarction *d*

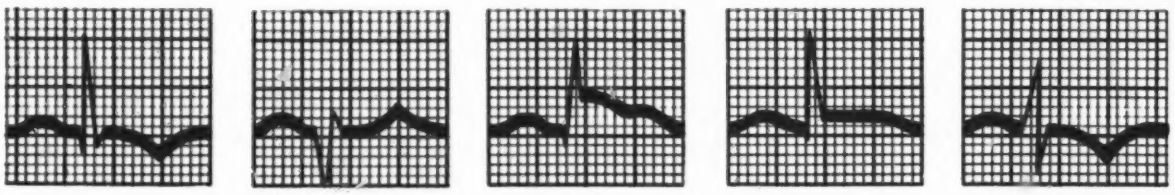
☐ ischemia ☐ injury ☐ infarction *e*

10

*a* infarction
*b* injury
*c* injury
*d* ischemia
*e* infarction

11

Check the myocardial state suggested by each diagram:



☐ ischemia ☐ injury ☐ infarction *a*

☐ ischemia ☐ injury ☐ infarction *b*

☐ ischemia ☐ injury ☐ infarction *c*

☐ ischemia ☐ injury ☐ infarction *d*

☐ ischemia ☐ injury ☐ infarction *e*

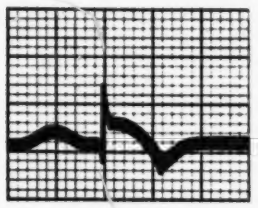
11

*a* ischemia
*b* infarction
*c* injury
*d* injury
*e* ischemia

12

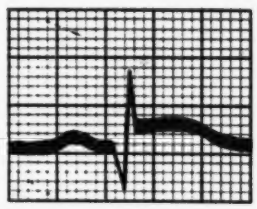
***A single pattern frequently displays a combination of abnormalities.***

**Under each diagram, check the box or boxes:**



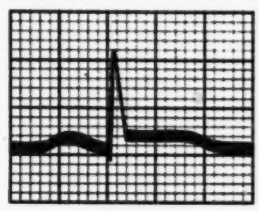
☐ ischemia
☐ injury
☐ infarction

*a*



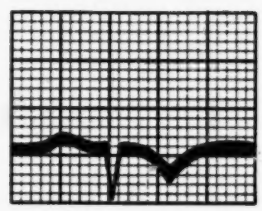
☐ ischemia
☐ injury
☐ infarction

*b*



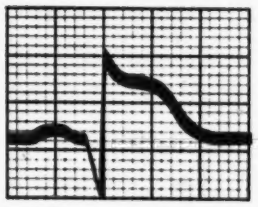
☐ ischemia
☐ injury
☐ infarction

*c*



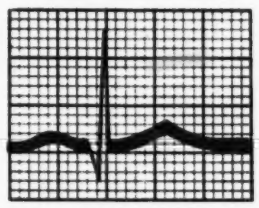
☐ ischemia
☐ injury
☐ infarction

*d*



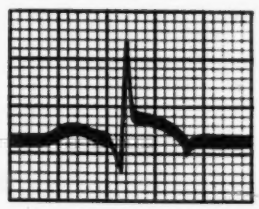
☐ ischemia
☐ injury
☐ infarction

*e*



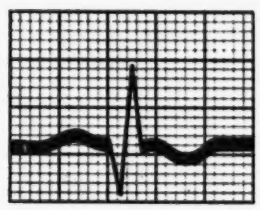
☐ ischemia
☐ injury
☐ infarction

*f*



☐ ischemia
☐ injury
☐ infarction

*g*



☐ ischemia
☐ injury
☐ infarction

*h*

12

*a* ischemia, injury
*b* injury, infarction
*c* injury
*d* infarction, ischemia
*e* injury, infarction
*f* infarction
*g* infarction, injury, ischemia
*h* ischemia, infarction

## E. Programmed Instruction in Underdeveloped Areas

A major pilot project for science teaching is currently being conducted in São Paulo, Brazil, under the joint auspices of UNESCO's Departments of Natural Sciences, Education, and Mass Communications and Brazil's IBECC. The objectives of this project are to demonstrate the applications of behavioral technology to the modern concept of science teaching. A programmed course on the physics of light which combines programmed texts, laboratory, and film is being developed in Portuguese, Spanish, and English versions by a team of about fifteen physics teachers from several different Latin American countries and Sweden. A fundamental aspect of the behavioral objectives of the course is that the student must learn the empirical and experimental bases of the physical abstractions called theories, and that he must learn to demonstrate and control certain physical phenomena in a laboratory setting.

In 1963 UNESCO also conducted programmed instruction workshops in Nigeria and Jordan. These workshops were designed to familiarize educators from these regions with the techniques of programmed instruction. Additional projects involving programmed instruction are being planned by UNESCO for 1964 and 1965.

# VIII. TEACHING MACHINES

The identification of programmed instruction and behavioral technology with teaching machines is due, in large measure, to the promotional and merchandising activities of some commercial companies who see in teaching machines a more tangible, and therefore more marketable, product than they do in programmed instruction. The economics of marketing hardware are far superior to the economics of marketing "intangibles," especially if the dramatic appeal of the teaching machine is considered. Furthermore, capability in behavioral technology is not easily available to commercial organizations wishing to enter this field. Since behavioral technology is a relatively recent development, experts are still scarce, and the few that exist are, by and large, securely situated.

This is not to say that teaching machines do not have a legitimate place in behavioral technology. Skinner himself coined the term "teaching machine" (57) and many serious psychologists concern themselves with the design of display devices. The purpose of a teaching machine is to prevent the student, by mechanical means, from looking at the correct answer before he has made his own response, and from looking ahead or behind in the frame sequence. It must be stressed, however, that no teaching machine has yet been developed that administers a program more effectively than does a programmed textbook. There are at least nine published studies that show that existing teaching machines are either no better than, or worse than, programmed texts (2, 5, 17, 18, 19, 26, 28, 37, 59).

The principal criticism of present-day teaching machines is their restrictive effect on programming techniques. A teaching machine consists of a housing with a window through which the frames of the program are displayed. The student usually moves the questions past the window by operating a mechanical roller, or by pushing a button to activate an electrical feeding mechanism. He makes his responses either by writing his answer in a space provided for this purpose, or by pushing another button to select one of several alternative answers which are offered (13).

In either case, the student's response is severely restricted: An answer window necessarily restricts the amount of writing the student can do for any given frame. Labeling or completing a diagram, or writing out a one-page mathematical proof, are virtually impossible responses. This restriction causes the programmer to confine himself to writing frames that require one-, two-, or three-word responses. Finally, the size of the window through which the frame itself is presented restricts the amount of material that can be presented at one time. In the type of machine that requires the student to select one of several alternative answers by pushing a button, the programmer must confine himself to "multiple-choice" items. Aside from the theoretical objections to this form of teaching (40), there is a distinct limit to what can be taught in this way. Most practical training tasks require the student to learn to write, compute, speak, or explain, not merely to choose one out of three or four alternatives.

Nevertheless, a number of workers in the field are attempting to develop a teaching machine that will overcome or minimize these disadvantages, and that will still allow the desired control. The ideal teaching machine would allow flexibility in the size of the frame, the size and mode of the student's response, and would be relatively break-proof. Any design that falls short of these specifications will have to compete with the programmed text, which is still, by all standards, the most effective teaching machine on the market.

## IX. ISSUES IN THE USE AND FUTURE DEVELOPMENT OF PROGRAMMED INSTRUCTION

### A. What Is the Role of the Teacher?

A good program enables the student to achieve a high score on the final examination which specifies what he is to learn. If the terminal behavior specifications are adequate and comprehensive in that they define the education problem completely, this is a sufficient result, and no teacher is needed.

In basic education, however, it is usually difficult to specify by means of an examination, or for that matter in any other way, all the things that are to be taught. Among these difficult-to-specify educational objectives are what we sometimes call intellectual curiosity, ability to ask the right questions, and ability to participate in interpersonal exchanges of ideas. Because these things are so difficult to specify and to measure, they are difficult to teach by programmed instruction. Here, the teacher is needed because the teacher, unlike the program, can answer the student's questions, and can adjust the instruction to the student more flexibly.

This implies, of course, that a teacher who uses programmed instruction should be able to perform these functions. They are functions which require competence and training. Thus, good teachers will not be replaced by programmed instruction. Programmed instruction will increase the effectiveness of good teachers by freeing them for the functions that demand them.

B. The Danger of Deteriorating Educational Objectives

Since programmed instruction affords an effective way of attaining educational objectives defined by tests and examinations, it will become tempting to confine educational objectives increasingly to these objectives at the expense of other, less easily defined, and yet possibly more important, objectives. If this temptation produces an actual trend, educational objectives will gradually deteriorate as a secondary, indirect consequence of programmed instruction. The best defense against this danger is an increased emphasis on careful appreciation of educational objectives so that those objectives which behavioral technology can handle may always be distinguished from those for which the teacher's art is still required.

C. Programmed Instruction and Teacher Training

The educational administrator who sees in programmed instruction a quick and easy solution to some of his most pressing problems may be induced to place the problem of teacher training and recruitment in a position of secondary importance. He may feel that proctors with little knowledge of the subject matter can adequately supervise large groups of students working on programs. The administrator who adopts this policy takes a step in the direction of lower educational objectives, since he is confining education to the objectives toward which present-day programs are directed.

Equally dangerous is the point of view that the same programs that are designed for the student can be used to first train the teachers. It is self-evident that such a program could just as easily teach the student directly, without the distortion introduced by an intermediary. Furthermore, this point of view also overlooks the fact that if the teacher is to concentrate on educational objectives which the program does not handle, then the teacher must receive training above and beyond that which programmed instruction can offer.

D. Administrative Problems

An educational system which utilizes programmed instruction will quickly have to confront certain administrative problems, the solutions to which may require modifications of the traditional system. Some of these problems are listed below:

1. Because of the self-pacing feature of programmed instruction, every student progresses at a different rate. Therefore, how should students be grouped into classes, if at all? How should students be promoted from grade to grade?

2. Because achievement is uniformly high, grades lose their utility as measures of achievement. Achievement must be described in terms of courses completed. How will this new description of achievement be accepted by the larger community, including government, industry, and institutions of higher education, who are accustomed to utilizing the traditional descriptions of achievement as screening devices?

E. Centralization of the Control of Education

As was explained earlier, the cost of developing quality programs is high, certainly beyond the means of the individual author. The result is that programs can be developed only by industrial, professional, governmental, or other agencies that have the means to finance program development. The individual textbook author and the small publisher may lose in importance as a contributor to education. The specification of curricula and educational objectives will increasingly devolve upon the "panels of experts" and "leading authorities" in the various subject matter fields. Such centralization is regarded by many as undersirable and even dangerous. As one surveys the field of programmed instruction, the beginning of this trend is already apparent.

## F. Quality Control

When products of behavioral technology are involved, the problem of quality control assumes broader dimensions than just giving the consumer his "money's worth" and the general desirability of "raising the standards." If a product of behavioral technology, such as a program, is taken seriously and utilized for what it is—a tool for modifying behavior—a great deal of dependence and responsibility is placed upon it. In the schools as well as in industry, programs will, inevitably, replace some of the functions now performed by teachers and textbooks. Thus, whenever a program is installed, this program assumes, ipso facto, a heavy burden of responsibility for the educational task in question.

For this reason, any defect of a program is magnified in its significance. A program may, of course, have any of a number of defects: It may be boring; it may teach wrong or trivial subject matter; it may stress the verbal instead of the empirical aspects of a subject matter; it may teach by rote instead of conceptually; or it may teach an unsound approach to a field. If a conventional textbook has these faults, it is much less serious. The student can easily switch from one textbook to another, and, of course, he can always resort to the teacher. If teacher and textbook both teach poorly, as is often the case, he can always simply "not learn." When taught by programmed instruction, on the other hand, the student has less protection, and he is likely to learn whatever the program is designed to teach.

The problem is an especially serious one because poor programs are easier and cheaper to produce than good programs. The high cost of producing a high quality program discourages expert definition of subject matter and objectives, thorough behavioral analysis, and adequate testing-revision procedures. The problem is immediately evident as one examines available programs. Much less evident is how this problem can be solved, or even attacked.

An interesting beginning has been made in the presentation of program performance specifications in teachers' manuals (15, 43) and in industrial technical reports (63, 68). Several contributions have also been made to the establishment of criteria for the assessment of programmed materials (12, 38, 49). To date, such contributions have been limited to a series of general considerations and guidelines. Chief emphasis has been given to the importance of performance data:

"Although the content which a program is designed to teach may be inferred from careful inspection of the program itself, external evidence based on student performance is needed to demonstrate how well the program actually teaches..." (12, p. 58).

"External evidence is recommended as the main basis for the evaluation of program effectiveness—in particular, test data obtained from using a program under specified conditions which provide dependable measures of gains produced in student achievement and of the time students require to achieve these gains" (12, p. 63).

Rothkopf points out with reference to the properties of a program which result from its design that "... the fact that a program has the prescribed properties is often impossible to detect by simple inspection of the program." Small-step design and low error rates are really "functional specifications which say what the program should do to the student. The presence of these properties can be guessed at but cannot be determined with certainty by inspection" (49, p. 33). He therefore urges that "the supplier of a program should be asked to attach to each program a label which specifies its performance characteristics" (49, p. 34).

The emphasis on performance data is useful insofar as an empirical check on claims is provided when such data are presented. Such data are generated as a natural consequence of the systematic design and production procedure described earlier, in Section V. It should be pointed out, however, that although such data provide practical norms as to whether a program is useful, it does not indicate the limits of what might be attained by superior programming. A given program may generate uniformly high scores on an adequate final examination, over a wide range of students, and with a low error-rate. But it may still be the case that the same material could be imparted in half the time through a superior and more efficient program. It is likely that useful measures of program efficiency or power, still to be achieved, will require further work in the area of behavioral design.

Performance data of the sort just mentioned are to be distinguished from descriptive accounts of programs in classroom use. In the latter situation the effect of a program interacts with lecture, reading, classroom discussion, and laboratory work. The interaction may be appropriate in the field setting, but data from such settings are of little more than testimonial value in any one case. In fact, instances have been reported where such "augmentation" has led to weaker performance.

G. Some Pseudo-problems

The problems raised above are serious and require correspondingly serious attention. There are also a number of other apparent problems which are often raised by teachers and educators as arguments against the use of programmed instruction. Some of these are:

1. "Programmed instruction will suppress individuality and will reduce individual

variation among students. Everybody will 'think alike.' " This argument reflects a failure to distinguish individual variation due to degrees of ignorance and degrees of misinformation, and individual variation due to differences in ability and personality. It is the latter type of individuality we value. It would appear that an effective program could allow this type of individuality to come to the fore by laying a firm foundation of knowledge.

2. "Programmed instruction is useful only for teaching rote material and straight facts, but not for teaching concepts and techniques of thought." This view is based on a misunderstanding of the nature of programmed instruction. Many thoughtful educators have arrived at this view on the basis of poor programs they have inspected. Clearly, the teaching of concepts and modes of thought does fall within the province of behavioral technology (42, 48).

3. "The personal element will be removed from teaching if programs are used." In fact, the reverse is true. In lecture situations where one teacher lectures to forty or fifty students, the personal element has already been removed to a great extent. With the world's teacher shortage increasing, meaningful contact between student and teacher is diminishing. It may reasonably be expected that the use of programmed instruction will free some of the teacher's time for conferences and discussions with students. Also, it may be pointed out that effective programs will prepare the student to benefit more from his already-limited personal contact with the teacher.

## X. SOME AREAS FOR RESEARCH

### A. Subject Matter Areas Which Have As Yet Received Little Attention

#### 1. Literacy

a. Reading and writing for children beginning school

b. Reading and writing for illiterate adults

This area is at present top-heavy with theory. Behavioral technologists express great confidence that the main technical problems could be solved by a suitably designed project. It would appear that an approach designed for one locality and one language might serve as a subsequent model for other areas and cultures.

2. Language Teaching

   a. Teaching adults to speak a second language

   b. Teaching adults to speak, read, and write a second language

   Here some good beginnings have been made by linguists and language teachers who have developed "language laboratory" courses. Nevertheless, a more formal and rigorous application of behavioral technology could produce some valuable advances.

3. Science Education

   While a great deal of work is currently being done in the teaching of science subject matter, little is being done in developing a methodology for teaching the many other skills needed by a scientist. This area is the subject of Science Education and Behavioral Technology (42).

4. The Teaching of Manipulative and Mechanical Skills

   Three years ago, when activity in the field of behavioral technology began to accelerate, much more was known about the teaching of manipulative and mechanical skills than about the teaching of verbal and intellectual skills. Today, the situation is reversed. More research and development is needed in the teaching of such skills as machine operation, construction skills like welding and carpentry, vehicle operation, and various manual manufacturing skills. Theoretical foundations for such efforts have already been laid; technological implementation, however, is still needed.

5. The Teaching of Social Interaction Skills

   Early efforts in this area are represented by the Effective Listening program described on page 12, and by the programs described in the section on Communication Skills, page 27. Thus it would appear that enough basic research has been done to justify some development efforts. The main areas in which programs of this type should be developed are:

   a. Project management

   b. Persuasion skills

c. Leadership skills

d. Group problem-solving skills

B. Problems in the Area of Production Technology

1. Task Analysis Techniques

Task analysis and the definition of objectives is a discipline that has been receiving increasing recognition in the human factors field, the military and industrial training fields, and in the field of systems analysis. Behavioral technology, however, is making demands upon this discipline that are difficult to satisfy. It appears that behavioral technology requires a specialized and behaviorally oriented approach to task analysis and specification of objectives. This is a major area for research.

2. Behavioral Analysis Techniques

This, of course, is the heart of the technology. Among the identifiable problems requiring research are:

a. What are the most useful ways of subdividing and categorizing chains, discriminations, generalizations, and concepts?

b. What types of information about chains, discriminations, generalizations, and concepts should the behavioral analysis provide for the programmer?

c. What are the most useful ways to tabulate and document this information so as to make it optimally usable by the programmers?

d. What is the most useful technique for developing the sequence of concepts in the program once the behavioral analysis has been completed?

e. What is the most useful way to present the behavioral analysis in the case of an audio-lingual communications skill program?

3. Evaluation Techniques

As was mentioned in an earlier section, the evaluation of a program is of critical importance to the using community. The chief problems are what to look for, and how to measure it.

Also of considerable importance is the evaluation of programs by the producing agency, during the production process itself. A literature in the field of developmental testing is gradually beginning to accumulate.

4. The Training of Program Production Teams and Project Management

   The production process described in Section V presupposes the availability of a team of specialists. Needless to say, these specialists must be trained. The problem of selecting and training the production team is one of the most difficult problems in production technology. The trained team must include a manager who knows how to coordinate and schedule the various aspects of the production operation. The management of programming projects is a field of specialization of its own, about which there is a great deal to be learned.

C. Problems of Implementation and Installation

1. Implementation and installation of manpower development projects where many interlocking skills are assembled into a functioning unit.

2. Implementation and installation of a management system where several levels of administration and management are trained to interact with each other in the desired manner. This situation is the counterpart of 1 above except that the interlocking programs involve communications and management skills.

3. Curriculum construction. Since the application of behavioral technology requires the specification of the entrance behavior and the terminal behavior for any program, it becomes possible to think of a programmed curriculum as a framework of interlocking parts, which can be assembled in any number of ways, providing always that the entrance requirements of a program are satisfied by the terminal behavior specification of preceding programs. Thus behavioral technology may open a new approach to curriculum research.

These are some of the main frontiers of behavioral technology, in the view of the authors of this article. Clearly, there are also many important areas of research in behavioral technology that have not even been mentioned. Only experience growing out of implementation programs can authoritatively tell us which areas of research will yield the richest returns.

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